# GAGE THICKNESS MEASUREMENT BY USE OF INDUCTIVE SENSORS

## Cross Reference To Related Applications

This application claims the benefit of copending U.S. provisional patent application serial No. 60/181,942 filed February 11, 2000, the teachings of which are incorporated herein by reference.

## Field of the Invention

This invention relates to the use of a linear analog sensor to measure thickness of non-metallic skin material, such as polymeric skin material. More specifically, the present invention relates to the use of a linear analog sensor to measure the thickness of polymeric skin material suitable for use on an automotive instrument panel, to thereby provide more accurate information regarding skin thickness for other manufacturing steps that require accurate skin thickness determinations, such as laser scoring or weakening of the skin at a desired location for placement of an air-bag deployment system.

## Background Of The Invention

In various commercial assembly applications, there remains a constant need to develop a reliable technique to more accurately provide information regarding thickness of a non-metallic component, such as a polymeric material, which includes plastic or elastomeric type skin material. Such information, of course, would be critically needed in those situations where the polymer material at issue requires another downstream manufacturing operation, which may rely upon skin thickness as a critical variable.

For example, in the automotive field, a variety of disclosures exist concerning the creation of a tear seam for the purpose of improving the performance of an air bag deployment system. Examples of such air bag cover tear seams are disclosed in U.S. Patent Nos. 5,072,967; 5,082,310; 5,316,822 and 5,632,914. As disclosed therein, tear seams are prepared by forming such seam in the backside of a polymeric skin material. In addition, the seams are provided in various configurations, with the most common having a C, H, U or X-shape and wherein the pattern ultimately defines the number of air bag deployment doors required in the substrate.

That being the case, in the course of manufacturing skin material for use on an instrument panel, wherein the skin must be weakened at selected locations, it is critical to have some reliable indication of skin thickness, so that the weakening, scoring or tear seam formation, which occurs in a downstream process, can be properly regulated. That being the case, there remains a constant need to develop reliable techniques to evaluate thickness in non-metallic/polymeric type skin materials.

Of course, to date, a number of techniques have been advanced to measure thickness of a given non-metallic part. For example, it has been known to use lasers or other optical means to scan the surface of a fixture, followed by a subsequent scan after the plastic skin or shell is placed therein. Such method has been found to provide inconsistent thickness measurements due to varying reflectivity of the surface and a variety of other unknown factors.

Accordingly, it is an object of this invention to overcome the disadvantages of prior art designs and provide a new apparatus and method for detecting part thickness in non-metallic/polymeric type materials.

## SUMMARY OF THE INVENTION

In broad aspect, the present invention relates to a linear analog inductive sensor apparatus that is employed to measure the thickness of a non-metallic/polymeric type material at any point along the surface thereof. In method form, the invention relates to placing the sensor in contact with the surface of the non-metallic surface, whose thickness is to be determined, wherein the non-metallic material is itself placed over a metallic target material. The sensor thereby detects and measures the distance between its contact point on the surface, to the target, which therefore provides an accurate and reliable measure of the non-metallic material thickness. The invention herein therefore can be applied to any non-conducting material, such as plastic or a composite/laminate material, rubber or fabric.

In further aspect the present invention relates to a process for measuring and recording the thickness of an automotive trim panel material to generate a cross-sectional thickness profile comprising the steps of contacting a first surface of the material at a plurality of positions with an inductive sensor, contacting a second and opposite surface of the material at a corresponding plurality of positions with a metallic object, converting the output of the sensor into a value that represents the thickness of the material at said plurality of positions, generating a cross-sectional profile of thickness in said material as between said plurality of positions, and communicating

said cross-sectional profile of thickness in said material to a controller which is in communication with a cutting assembly to cut said material to a desired thickness, wherein said controller adjusts the thickness of a cut into said material based upon said cross-sectional profile thickness in said material to provide a cut of desired thickness.

In alternative embodiment the present invention relates to a process for measuring and recording the thickness of an automotive trim panel material to generate a cross-sectional thickness profile comprising the steps of contacting a first surface of the material at a first position with an inductive sensor, contacting a second and opposite surface of the material with a metallic object, converting the output of the sensor into a value that represents the thickness of the material at said first position, contacting said first surface of the material at a second position with said inductive sensor, contacting a second opposite surface of the material at said second position with a metallic object, converting the output of the sensor into a value that represents the thickness of the material at said second position, and generating a cross-sectional thickness profile in said material as between said first and second positions.

In yet further alternative embodiment, the generated cross-sectional thickness profile is communicated to a controller which is in communication with a cutting assembly to cut said material to a desired thickness, wherein said controller adjusts the thickness of a cut into said material based upon said cross-sectional profile thickness in said material to provide a cut of desired thickness.

## BRIEF DESCRIPTION OF THE DRAWINGS

**FIG. 1** illustrates the inductive sensor of the present invention before application to the surface of indicated plastic shell material.

**FIG. 2** illustrates the inductive sensor of the present invention as applied to the indicated plastic shell material.

**FIG. 3** illustrates the use of the inductive sensor herein, as applied to an automated robotic assembly.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As noted, the invention herein relates to a linear analog device for the measurement of part thickness. Preferably, the analog device is an inductive sensor made by OMRON, Model E2CA-X2A, which itself is connected to an E2CA-AN4D amplifier unit.

The sensor is then positioned on the surface of the non-metallic part to be measured. With attention to **FIG. 1**, as shown therein, the inductive sensor **10** is shown positioned above the non-metallic material surface **12** to be measured. Such non-metallic material may include any type of material that is non-conductive, such as synthetic polymeric material, including, but not limited to a thermoplastic, thermoplastic elastomer, thermoset material, etc. More specifically, non-metallic material **12** may include a thermoplastic polyester or polyurethane type material, in particularly, a polyurethane skin material, poly(vinyl chloride), or other types of polymeric material used as skin material on automotive instrument panel applications.

As also shown in **FIG. 1**, the non-metallic material **12** is positioned over a conductive metallic material **14**, which ultimately serves as the target for the inductive

device **10**. With attention directed at **FIG. 2**, inductive sensor **10** is positioned in contact with non-metallic material **12**, at location **16**, over conductive target **14**. At such time, sensor **10** will provide measurement of the distance or thickness **18** from sensor **10** to target **14**. Furthermore, although not shown, sensor **10** can be located anywhere along non-metallic material **12**, to provide a reliable statistical distribution of thickness **18** for the purposes of properly informing other downstream manufacturing operations that require an accurate assessment of thickness values.

In accordance with the present invention, which has been found to be preferably applied to the measurement of a skin thickness in a non-metallic material (e.g., polyurethane elastomeric skin) prior to application on an automotive instrument panel, various levels of thickness have been successfully evaluated. For example, sensor **10** conveniently provides thickness determinations between 0.001" – 0.500", and at all ranges there between, at reducing thickness values of 0.001". For example, thickness determinations have been established between values of 0.002" – 0.499". 0.003"-0.498", etc. In a most preferred embodiment, thickness values between 0.020" – 0.065" are determined, which is a typical range for a non-metallic skin material in an automotive instrument panel application.

With respect to the target material **14**, as noted, such material is conducting material, such as stainless steel, which thereby communicates with the sensor **10** to provide a selected thickness determination. Preferably, such target material is stainless steel at a thickness of 0.010", but other thickness can be used, provided it is sufficient to communicate with device **10**.

Also, as shown in **FIG. 2**, surrounding the target material **14** is a nest or fixture **20**, which supports the target material **14** so that it is properly positioned to communicate with the sensor **10** as disclosed herein. Fixture **20** may itself be conveniently made from a thermoset resin such as an epoxy resin, with sufficient rigidity to serve as a support structure.

In an alternative embodiment, the thickness of the non-metallic material **12**, for example an automotive instrument panel, is measured using the sensor **10** while the panel is still in the mold. Instrument panels can be formed using many different molding processes. Many instrument panels are formed using a slush molding process. These molds are typically formed of a metallic material such as nickel. After the panel is formed, but before it is removed from the mold, the thickness of the part can be measured and stored for later use. The sensor **10** uses the nickel mold as the target to determine the thickness of the panel. The sensor can measure the thickness of the panel along a predetermined path. The predetermined path may be a path where an air bag opening will be formed by a later process. The thickness of the part along the predetermined path for a corresponding panel can be saved in memory for later use when forming a score line for an airbag deployment section.

Also, as can be appreciated, the sensor device **10** may be conveniently applied to an automated robotic type assembly, such that the robotic arm selectively positions the sensor device **10** at a desired location for thickness evaluation. In that regard, it has been found that an important and useful aspect is to ensure that the sensor device **10** is connected to the robotic arm via a flexible or spring-loaded mechanism, such that the

robotic arm can position the sensor **10** on the surface, and the flexible mechanism there-between ensures proper contact with the surface for a desired thickness measurement. Stated another way, the placement of the sensor **10** on a flexible mechanism or spring loaded assembly allows the robotic arm to position and align the sensor **10** on a given surface, and apply pressure thereto, and any excess pressure would be relieved by the flexible mechanism, while ensuring that the sensor **10** provides appropriate surface contact to allow for proper thickness measurement.

The preferred inductive sensors for use herein are linear analog inductive sensors. They are available in versions that produce either 4mA to 20mA output signals, or a 0V to 10V type output signals. Accordingly, such current output or voltage output is then conveniently correlated to part thickness by standard calibration techniques using samples of known part thickness.

In an even more preferred embodiment of this invention, and as noted above, the inductive sensor herein is made to output its thickness reading to an analog/digital (A/D) converter, which digital signal is then inputted to a computer controller responsible for adjusting the thickness of a score line to be imparted to a polymeric skin material, which material is employed for the purpose of preparing an airbag deployment section on an automotive instrument panel. Such digital signal can be conveniently delivered to such computer controller by a computer serial connection, USB cable connection, etc. That being the case, the inductive sensor herein, as coupled to, e.g., the computer controller on a laser scoring apparatus, would provide the laser apparatus reliable information on polymeric skin thickness, for the purpose of forming a

controlled thickness tear seam in any desired configuration. The invention herein therefore is directed at an automated system, comprising the inductive sensor, coupled to a downstream manufacturing operation (such as laser scoring), through the use of a computer interface, which accepts thickness determinations and considers such information as applied to said given downstream manufacturing operation.

In addition, the inductive sensor may also be coupled to an upstream molding operation, through a computer interface, which accepts thickness determination and considers such information as applied to said molding operation thereby instructing said molding operation to either increase or decrease thickness as may be desired. Control of thickness may be accomplished, e.g., by adjusting the amount of material charged into the mold, mold temperature, mold cooling, molding pressure and/or time for the overall molding cycle.

Finally, attention is directed to **FIG. 3**, which as noted above, illustrates the use of the inductive sensor holder as attached to an automated robotic assembly. Specifically, an SMC air cylinder (NCMC 106-0200C) is shown generally at **22**, which contains a pair of air discharge openings **24**, which contains a spring inserted therein (not shown). A shaft distance of approximately 2.25" is set between the end of the cylinder **22** and the top of the sensor holder **26.** The sensor holder is threaded onto the shaft, along with a locking nut **28**. A nut is placed at **29**.

At **30** is illustrated the preferred Nachi robot mounting adaptor with a length of about 7/8". A machined brass adaptor is shown at **32**, along with a threaded insert at **34**, and a plurality of locking screws identified at **36**. The overall length of the robotic

assembly shown in **FIG. 3** is about 10.75", with a spring size therein (not shown) of 2.0" x 5/8".